Concepts of Imaging and Knobology

Pravin Patil, MD FACC FASE
Associate Professor of Medicine
Director, Cardiovascular Disease Training Program
Lewis Katz School of Medicine at Temple University

Disclosures

- ✓ No relevant financial disclosures

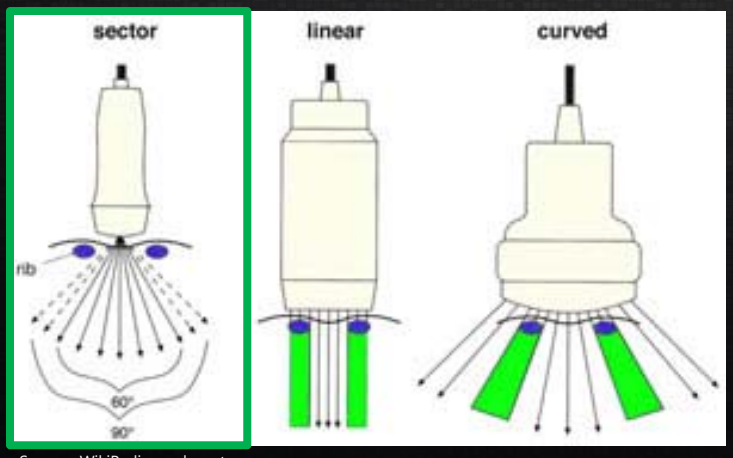
Echocardiography

- ✓ Tomographic Imaging
  - Echo is a "thin slice" imaging tool like cardiac CT, MRI and nuclear imaging
  - However, images are not automatically acquired
  - Achieved by probe manipulation, acoustic windows, patient positioning, balancing of artifacts and image processing
- ✓ The ability to optimize the image acquisition and processing is part of competency in echocardiography

"Knobology"

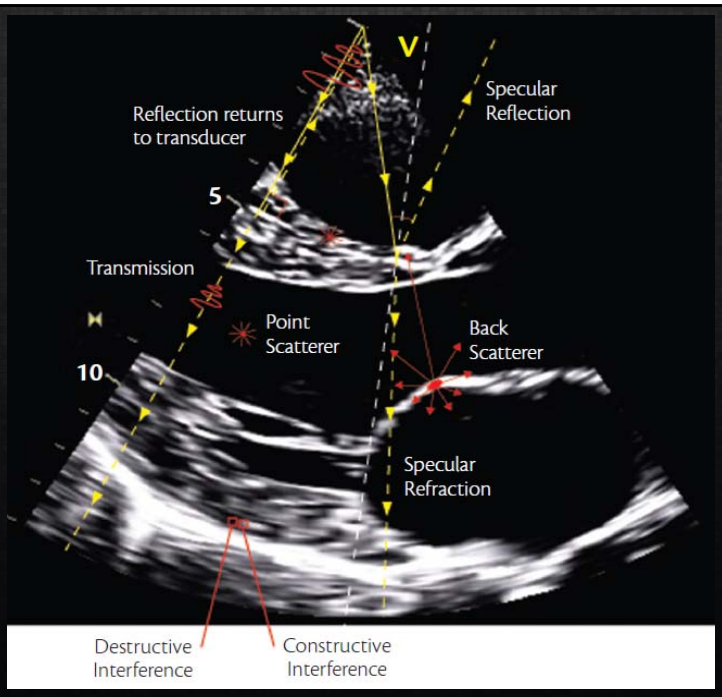
Source: Philips, GE, Siemens, Esaote, Toshiba

Ultrasound Probe



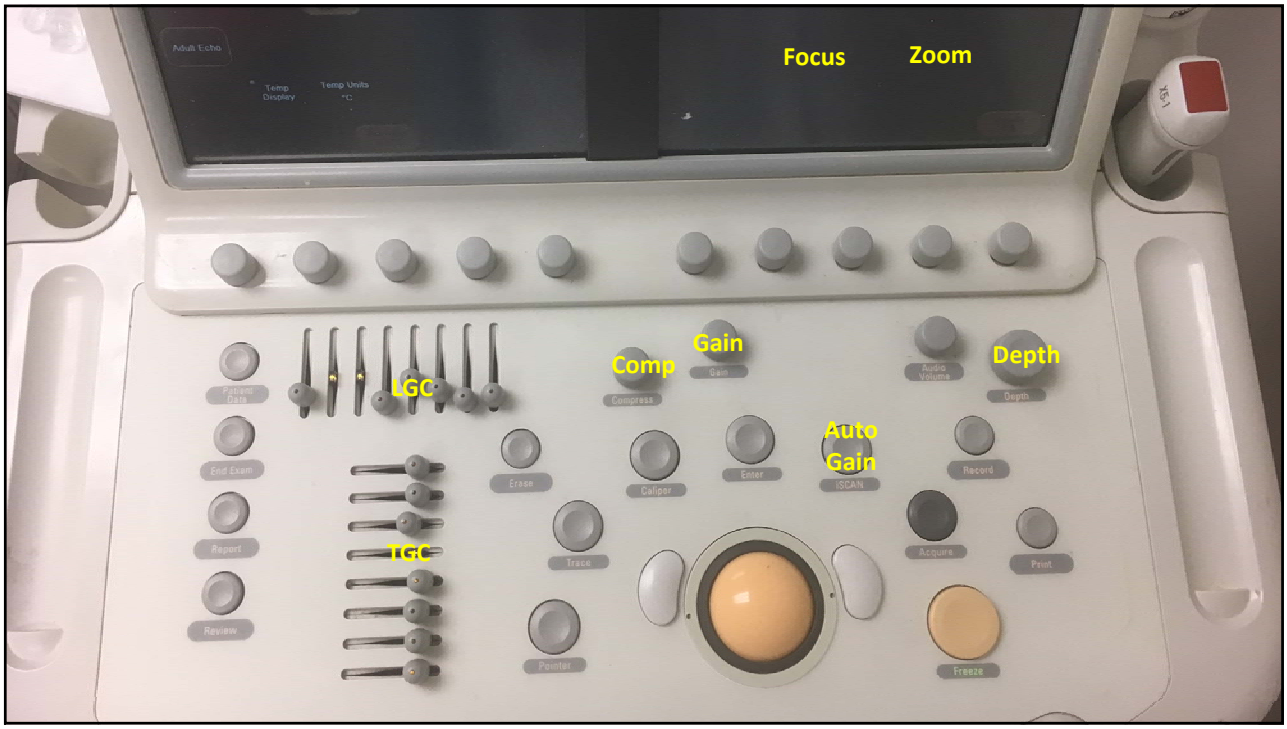
Source: WikiRadiography.net

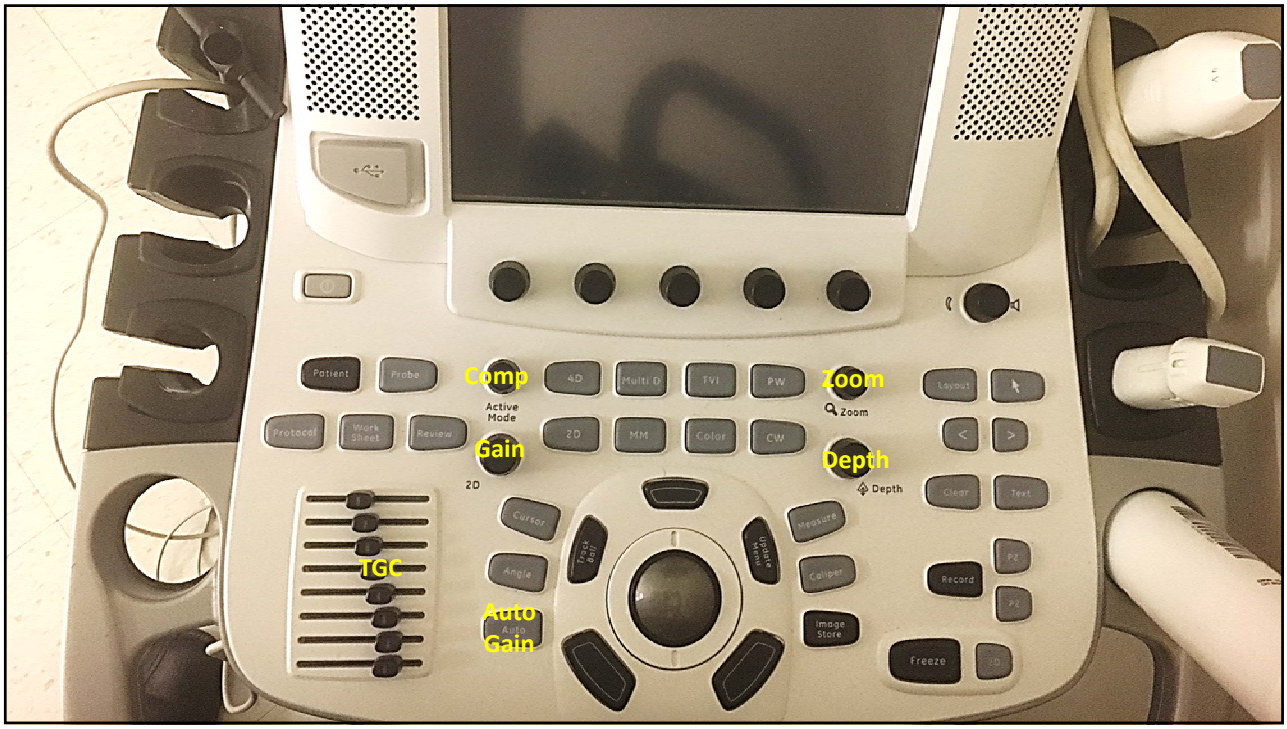
Phased Array



Garbi, M. The EAE Textbook of Echocardiography 2011

Machines and Knobs

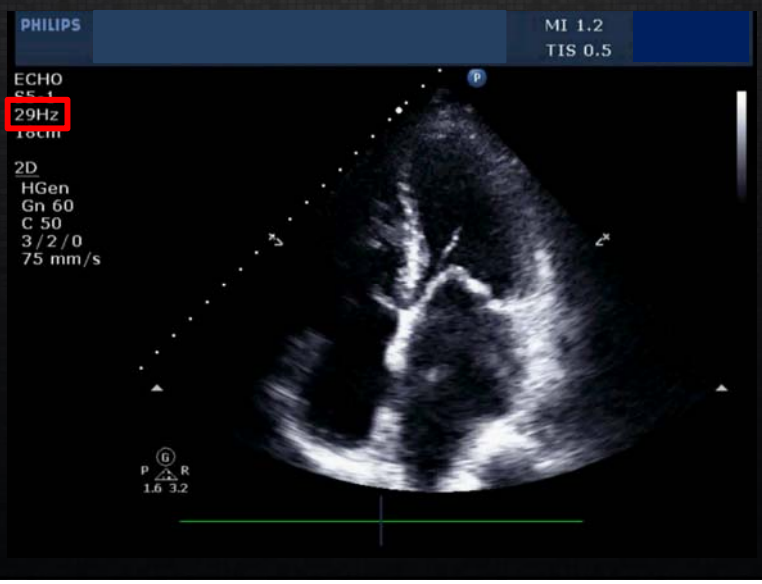

Focus
Zoom
Gain
Comp
Depth
LGC
Auto
Gain
TGC


Comp
Active
Mode
Zoom
Zoom
Gain
2D
Depth
Depth
TGC
Auto
Gain

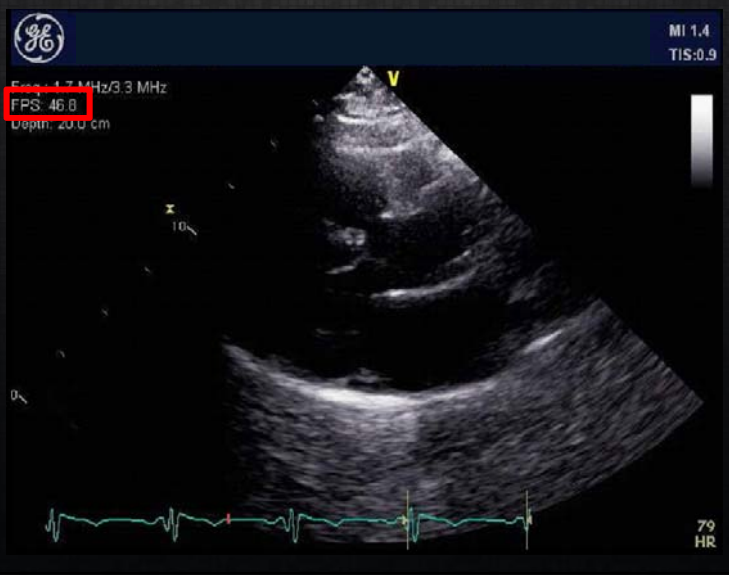
Rise of the Touchscreen and Trackpad

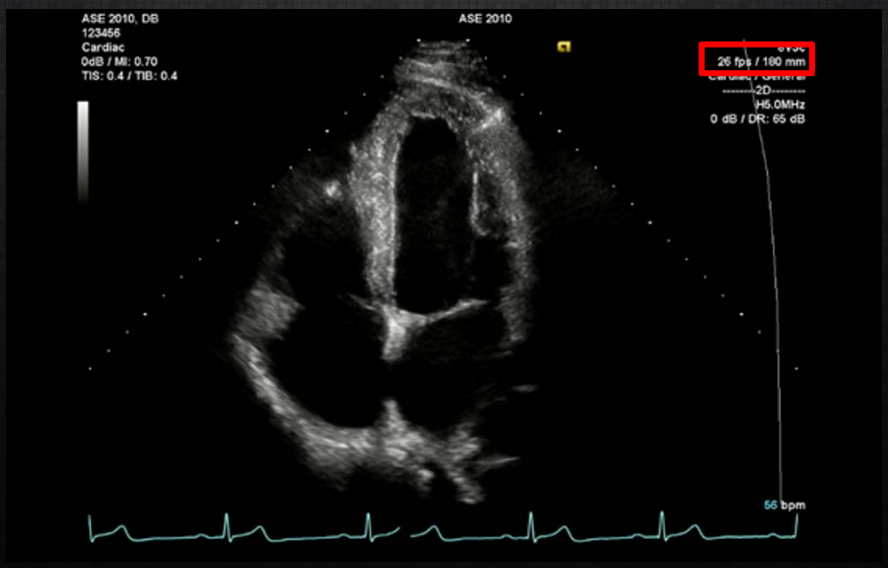
Source: Philips Healthcare, GE Healthcare

Echo Screen Anatomy



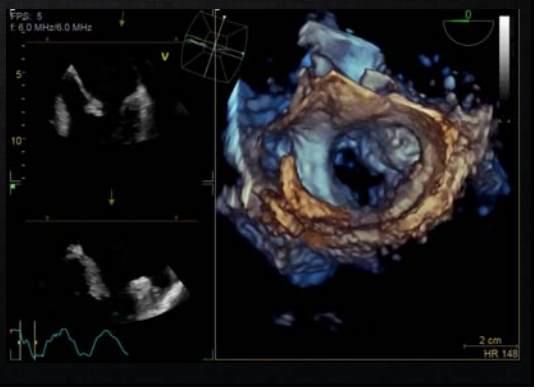
Echo Screen Anatomy



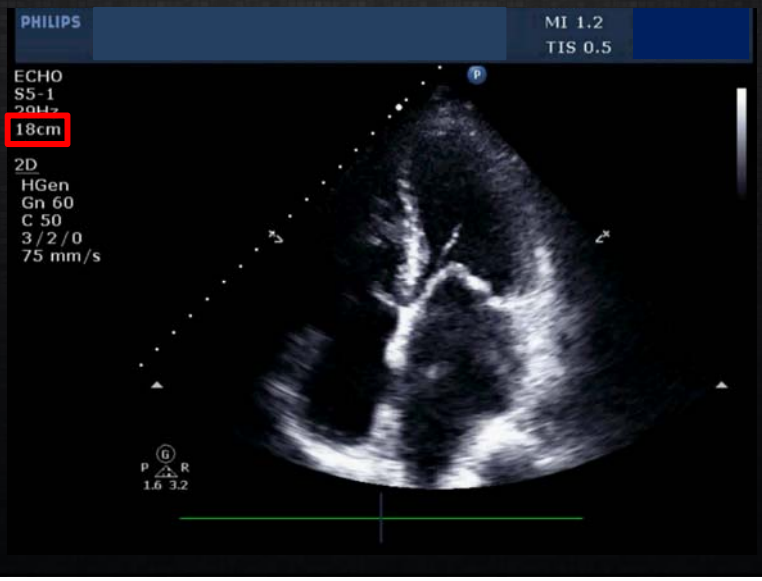


Frame Rate

- ✓ Temporal Resolution
  - Limited by line density and time to scan
  - Improves with narrow sector width
  - Unless line density decreases
- ✓ Appearance
  - FR <15 Hz appear choppy
  - FR >15 Hz appear smooth

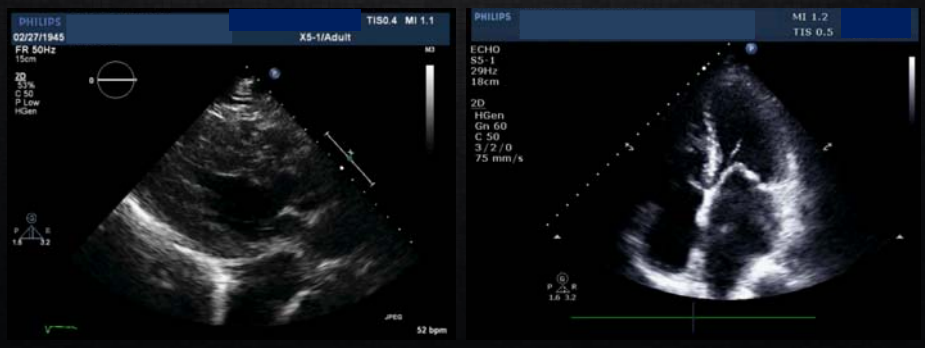


Echo Screen Anatomy

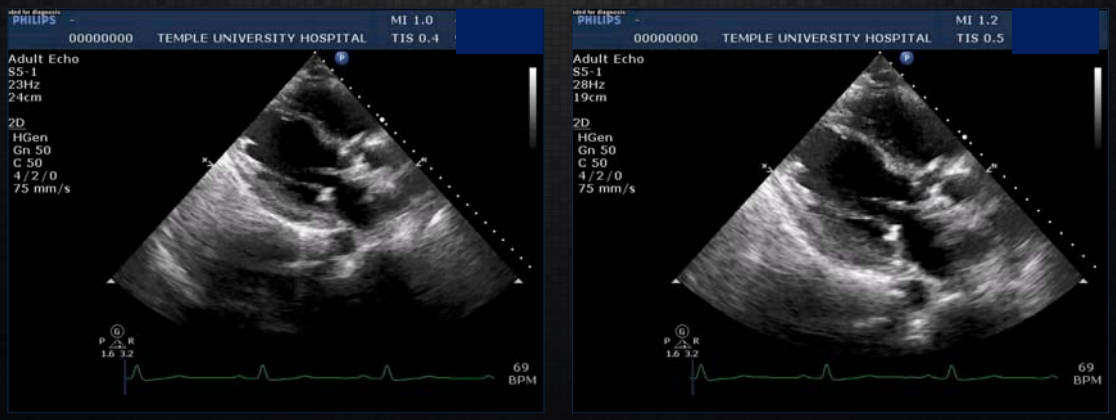


Imaging Depth

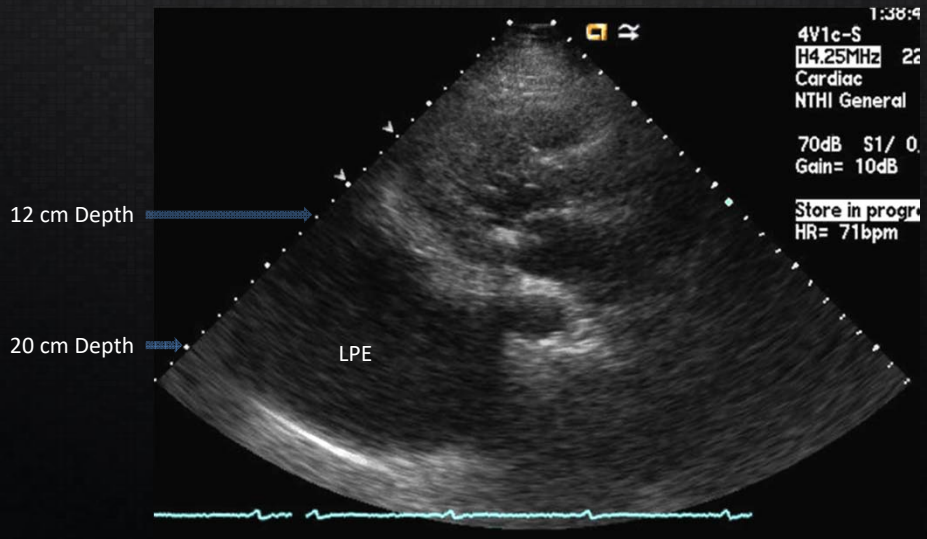
- ✓ Imaging Depth
  - Start with larger than needed
  - Adjust to place ROI approximately ¾
  - Leave small area behind to observe useful artifacts like shadowing



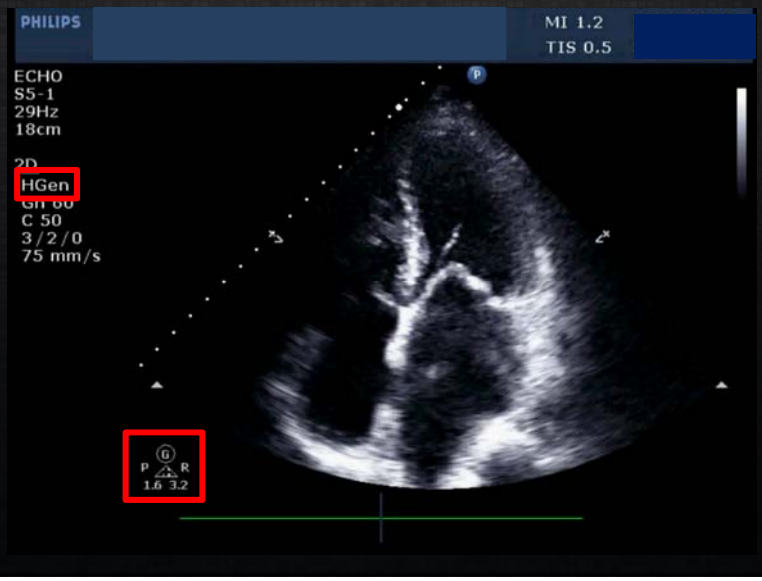
Depth

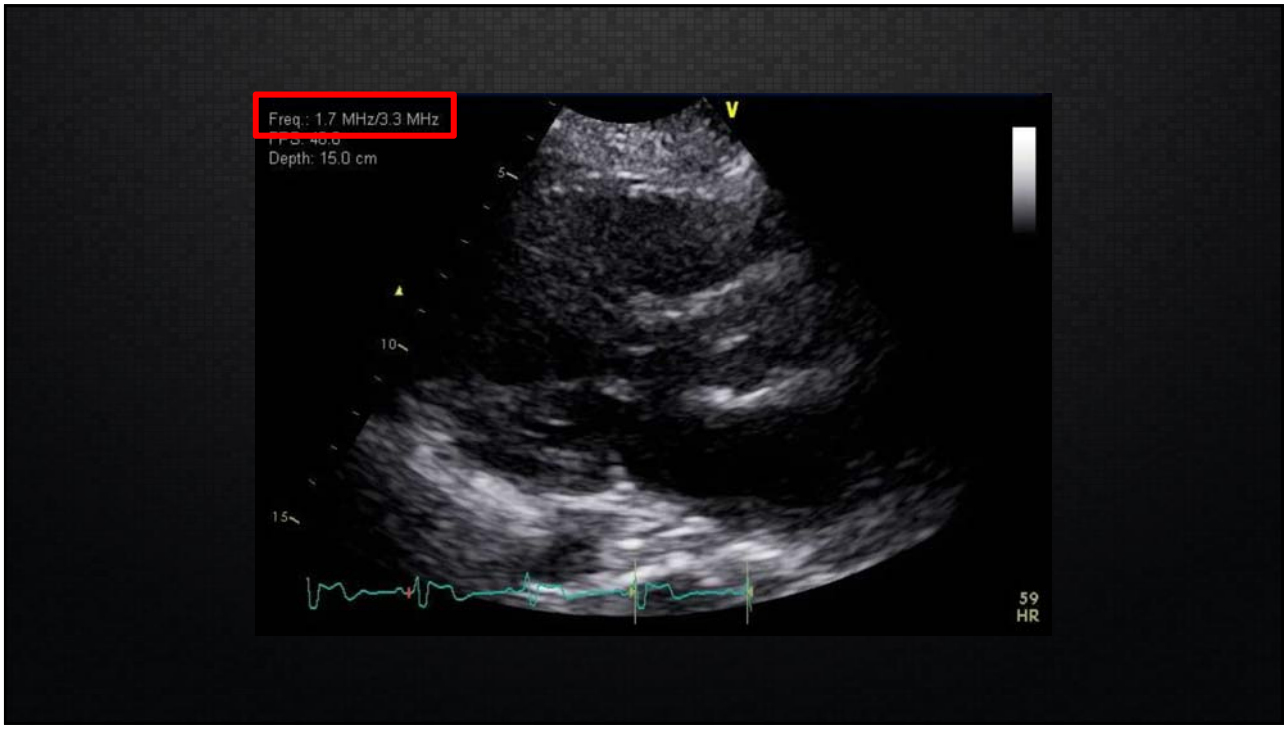


Depth

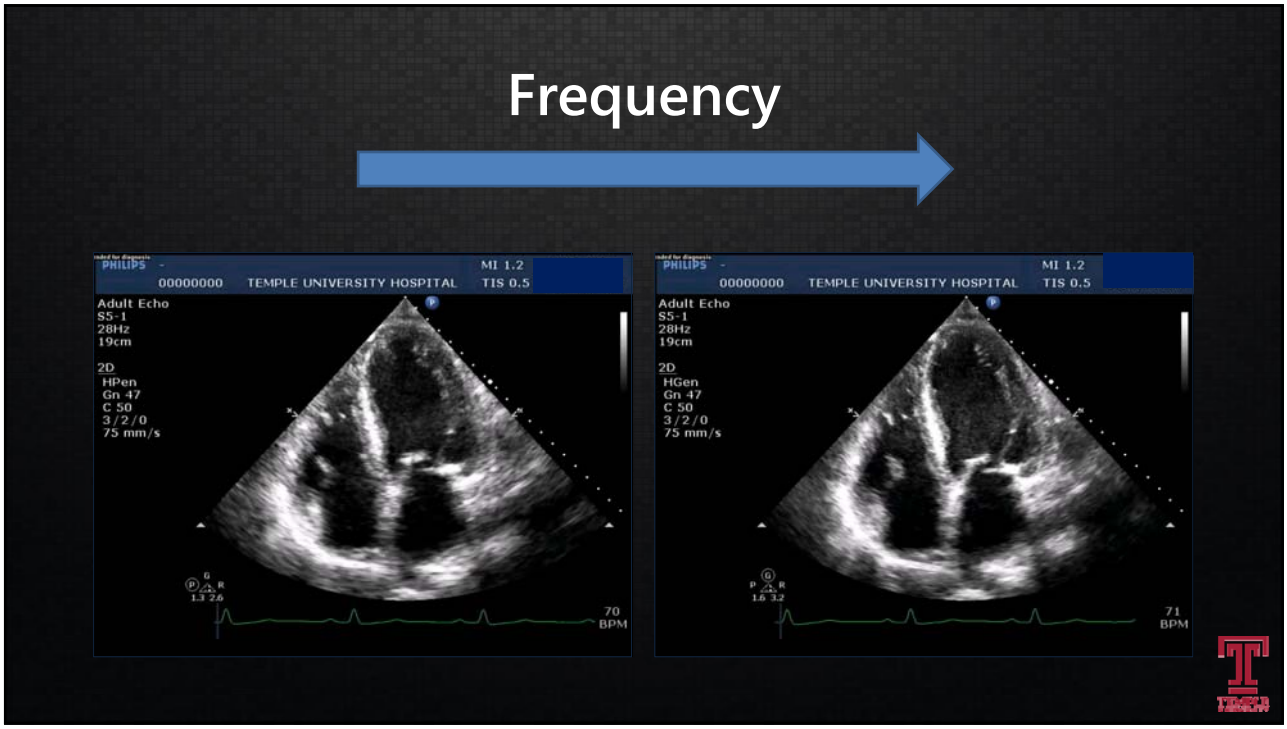


Echo Screen Anatomy

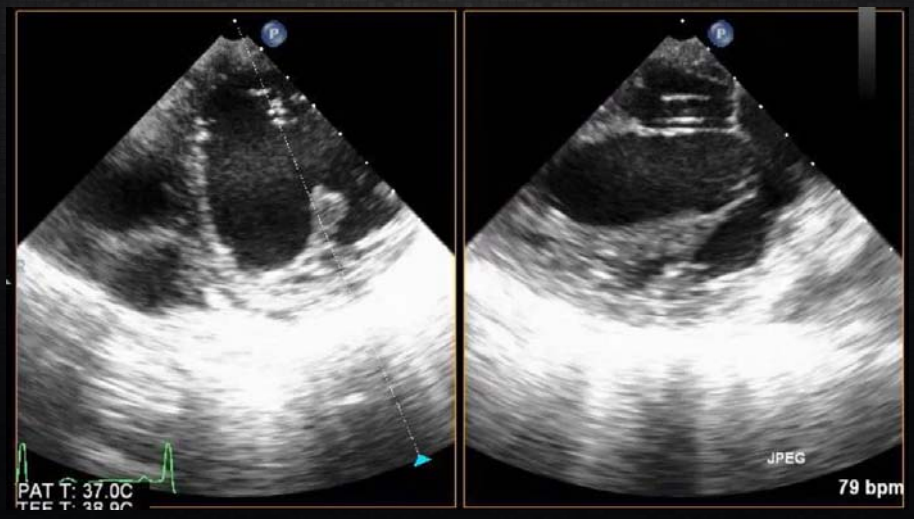



Freq.: 1.7 MHz/3.3 MHz
Depth: 15.0 cm
V
5
10
15
59
HR

Frequency


PHILIPS
00000000
TEMPLE UNIVERSITY HOSPITAL
MI 1.2
TIS 0.5
Adult Echo
S5-1
28Hz
19cm
2D
HPen
Gn 47
C 50
3/2/0
75 mm/s
70
BPM
PHILIPS
00000000
TEMPLE UNIVERSITY HOSPITAL
MI 1.2
TIS 0.5
Adult Echo
S5-1
28Hz
19cm
2D
HGen
Gn 47
C 50
3/2/0
75 mm/s
71
BPM

Axial Resolution × Frequency



Zoom

Larger Pixels, Higher Frame Rate
Not Higher Axial Resolution

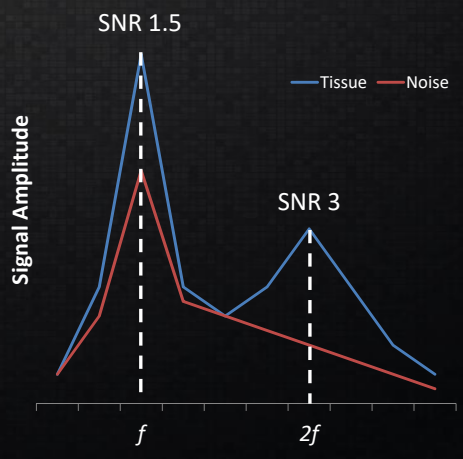
Harmonic Imaging

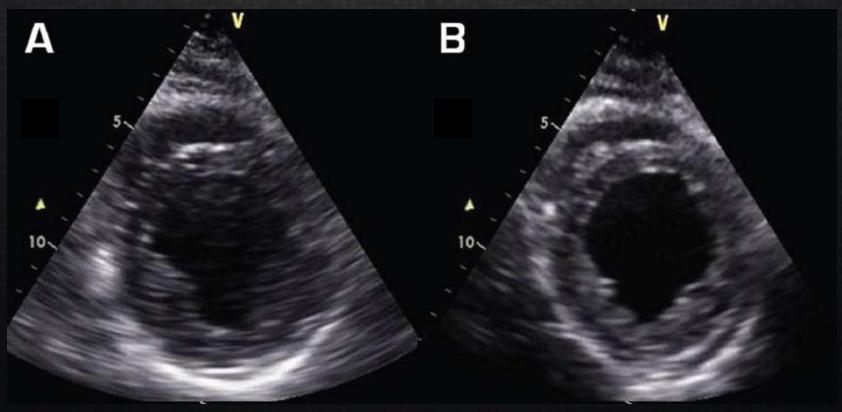
- Improves signal-to-noise ratio
- Contrast
  - Non-linear resonance of bubbles to compressions and rarefactions of ultrasound wave
- Tissue (incidental discovery)
  - Related to propagation of sound through the myocardium
  - Non-linear response due to higher speed during compression than in rarefaction.

McCulloch, et al. JASE 2000

Tissue Harmonic Imaging

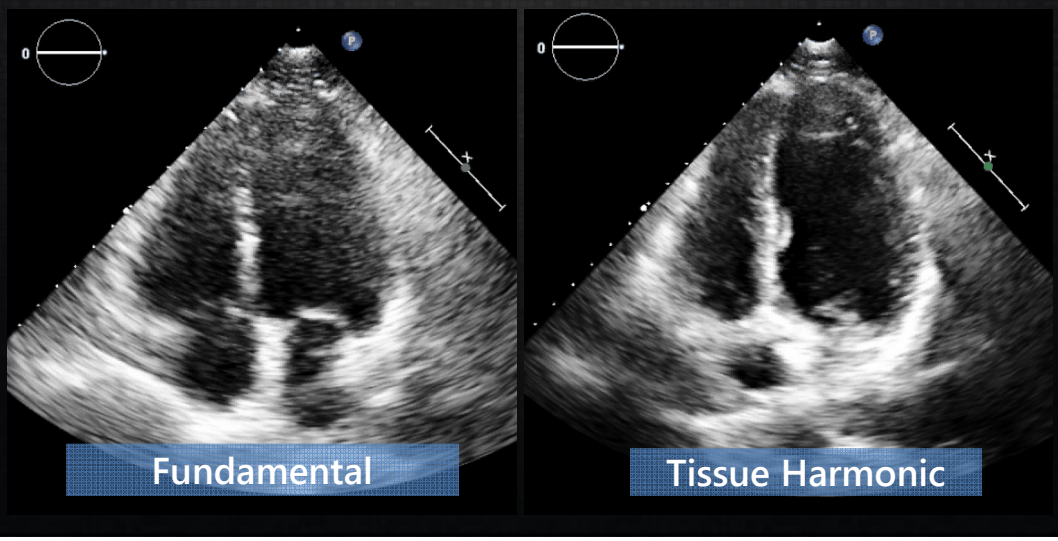
- ✓ Non-linear distortion of acoustic signal in tissue generates harmonics
- ✓ Noise/artifacts generate no significant harmonic
- ✓ Tissue Harmonic Imaging takes advantage of increased SNR



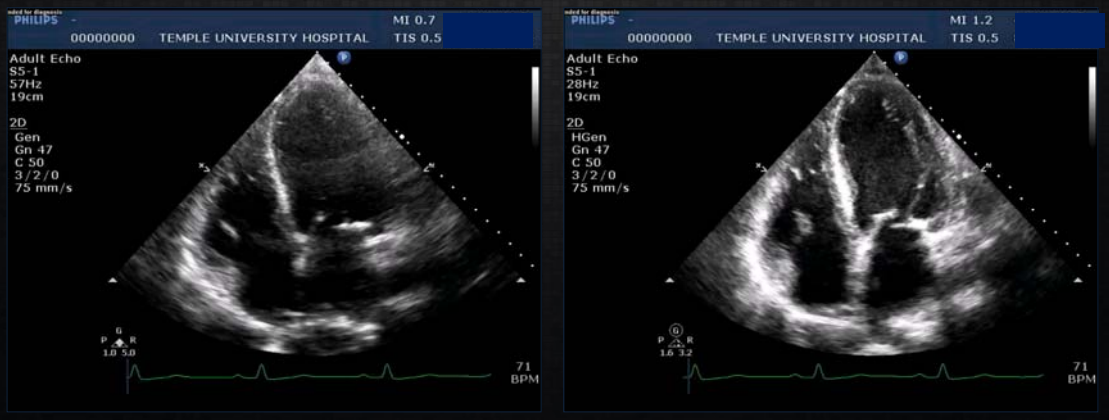


Garbi, M. The EAE Textbook of Echocardiography 2011

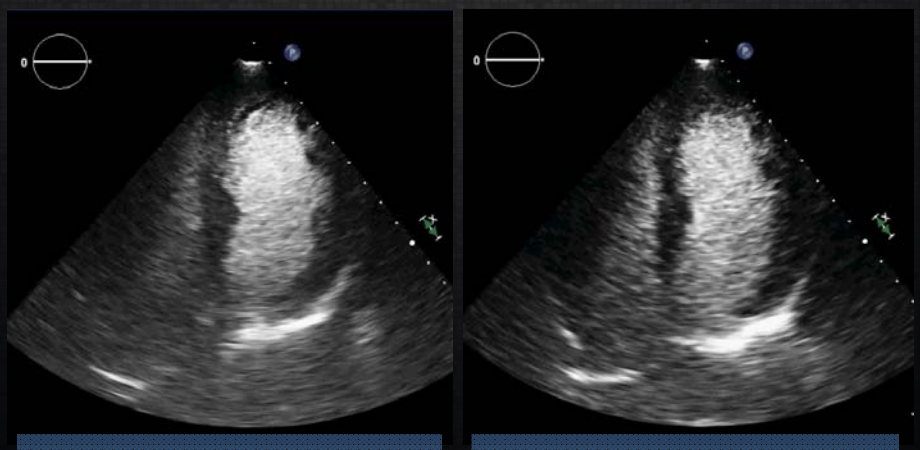
Tissue Harmonic Imaging



Tissue Harmonic Imaging



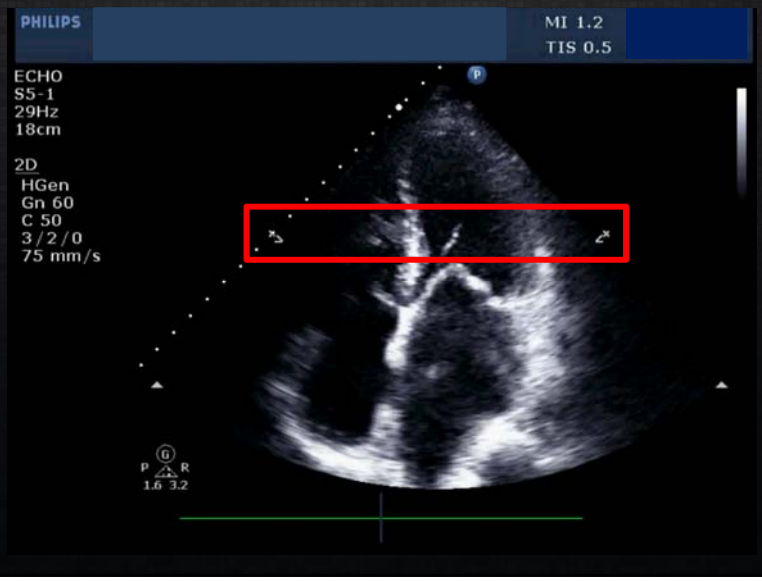
Bubbles Have Harmonics too..



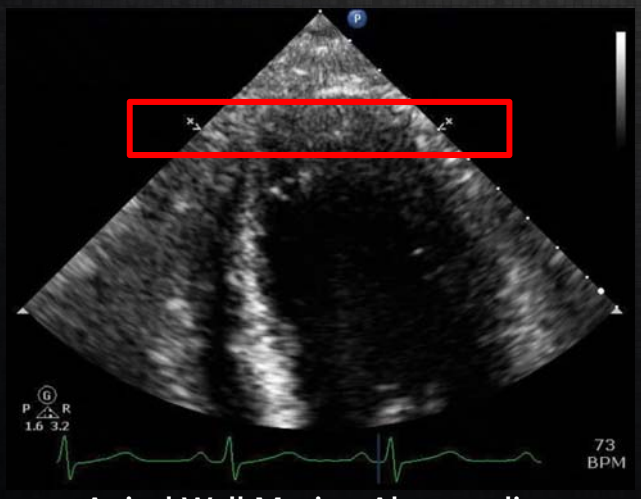
Harmonics 1.3/2.6 MHz

Fundamental 1.6 MHz

Echo Screen Anatomy



Lateral Resolution



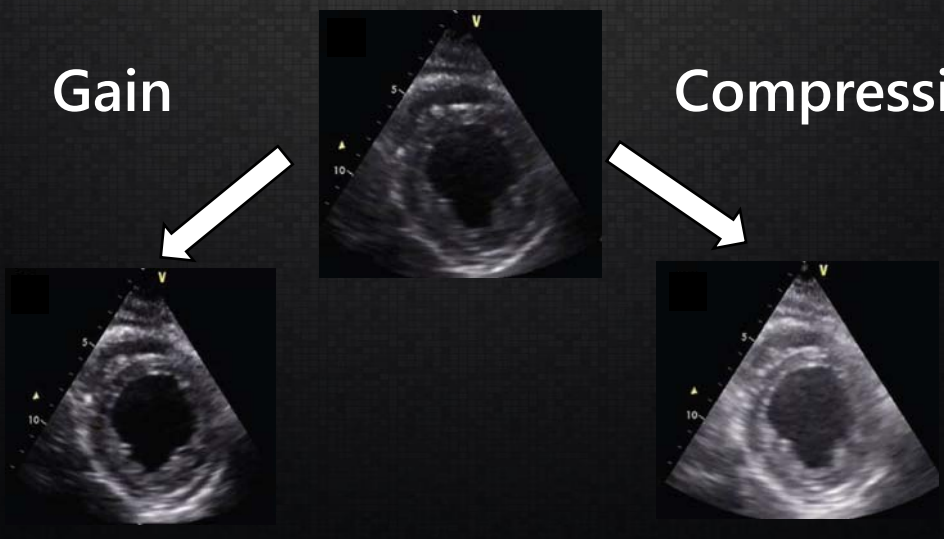
Apical Wall Motion Abnormality, Concern for LV thrombus

- Focal Zone / Focus
- Increased ability to discern two separate objects at the FZ

Echo Screen Anatomy

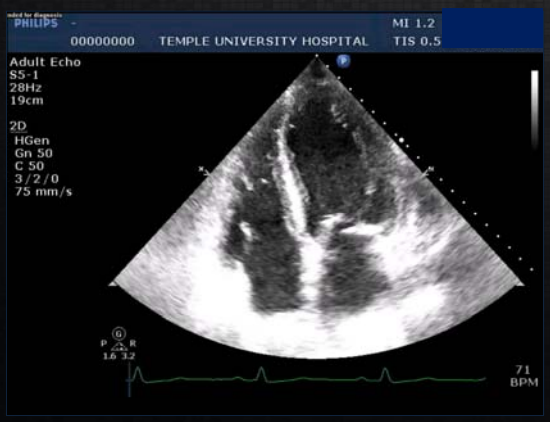
Gain

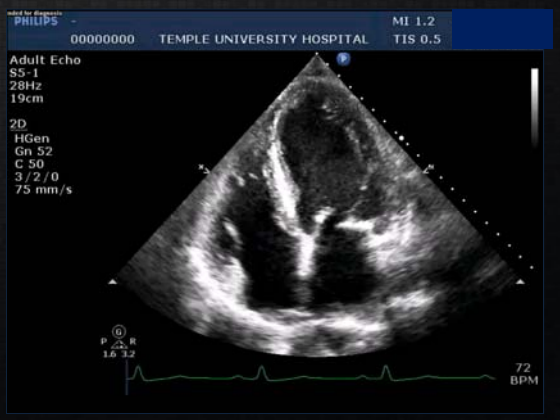
Compression



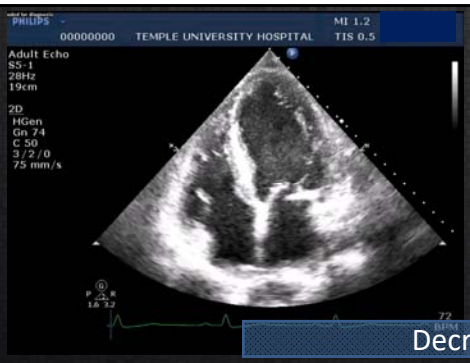
Adapted from Garbi, M. The EAE Textbook of Echocardiography 2011

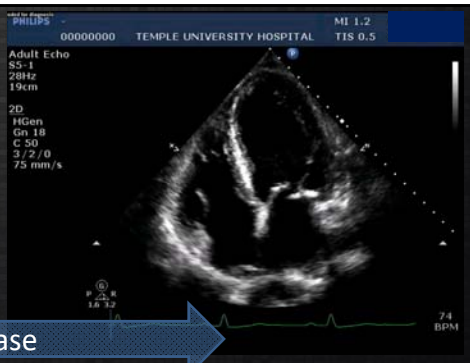
Auto Gain





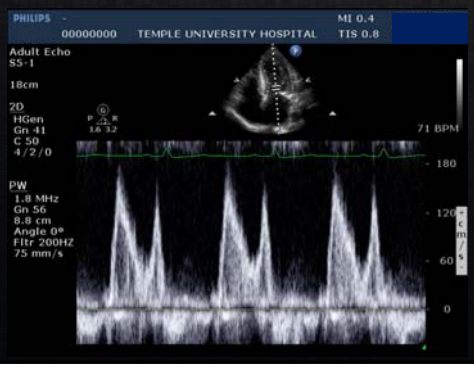
2D Gain

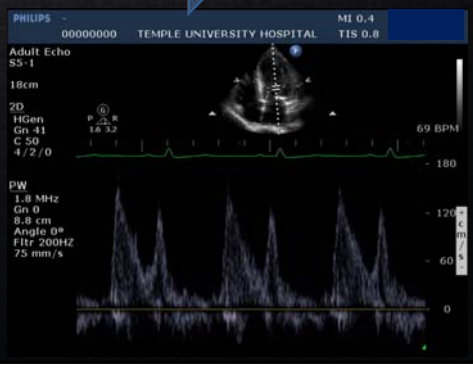




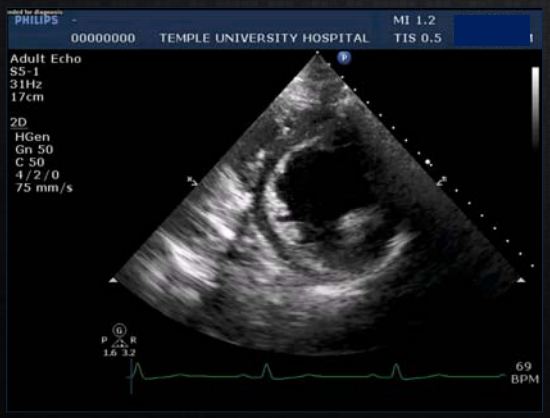
Decrease

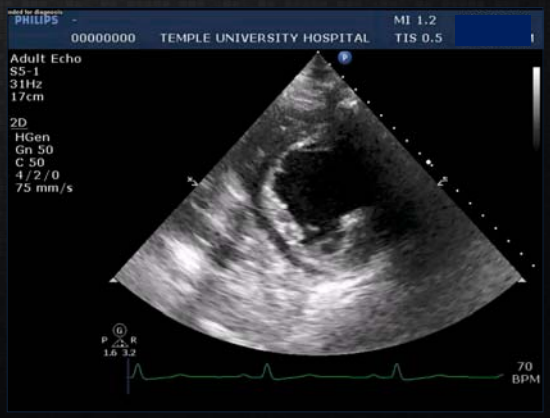
Doppler Gain



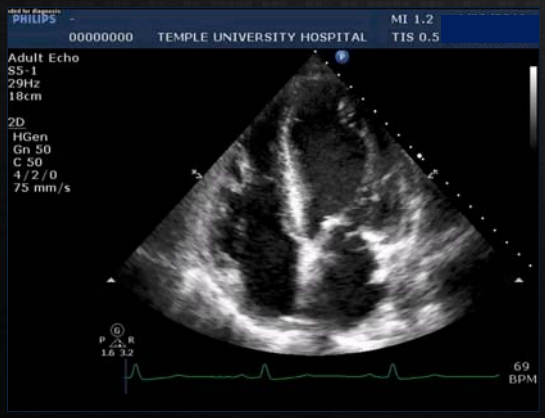


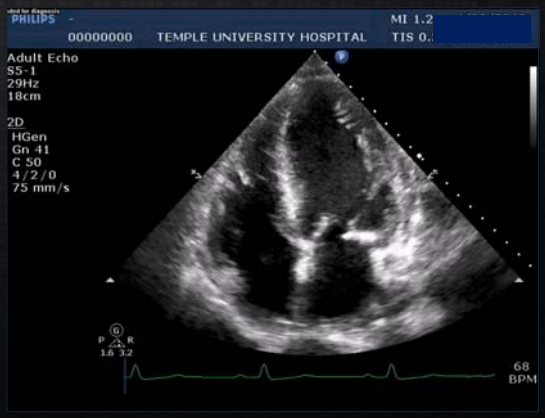
Time Gain Compensation (TGC)



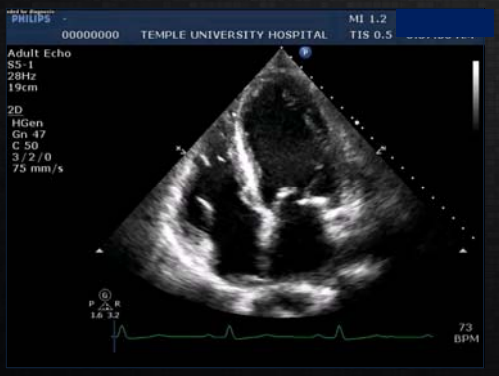


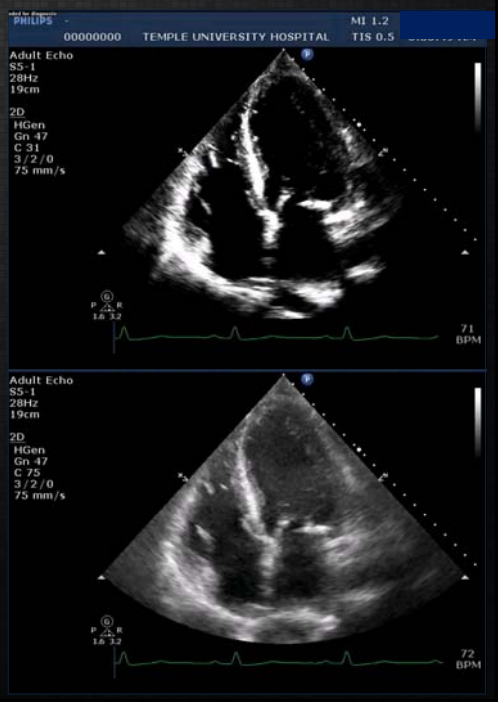
Lateral Gain Compensation (LGC)



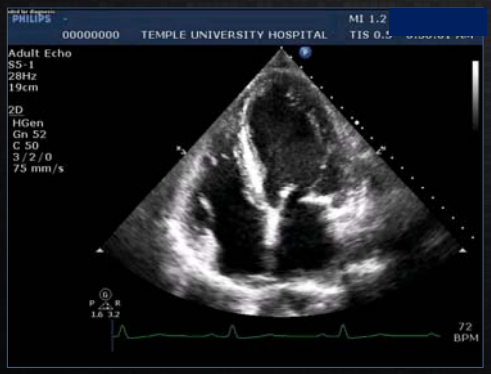


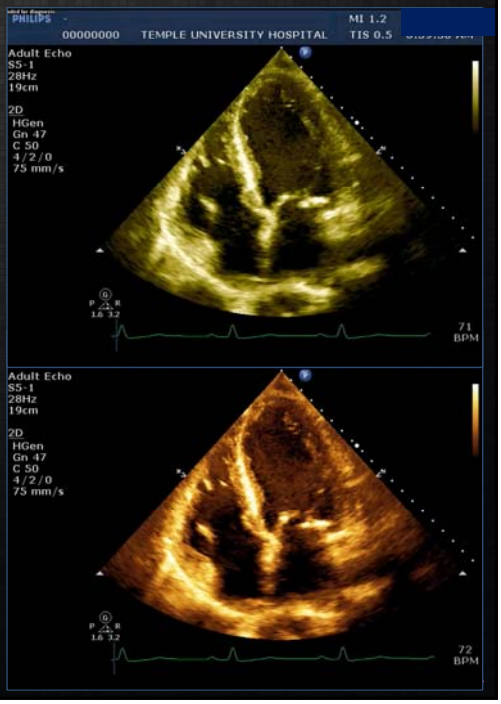
Compression





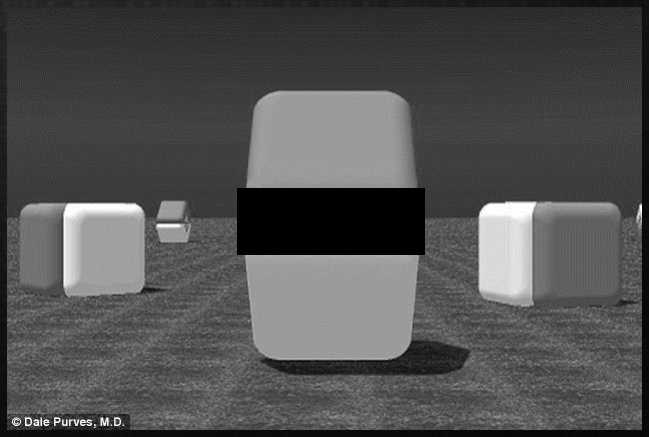
Color



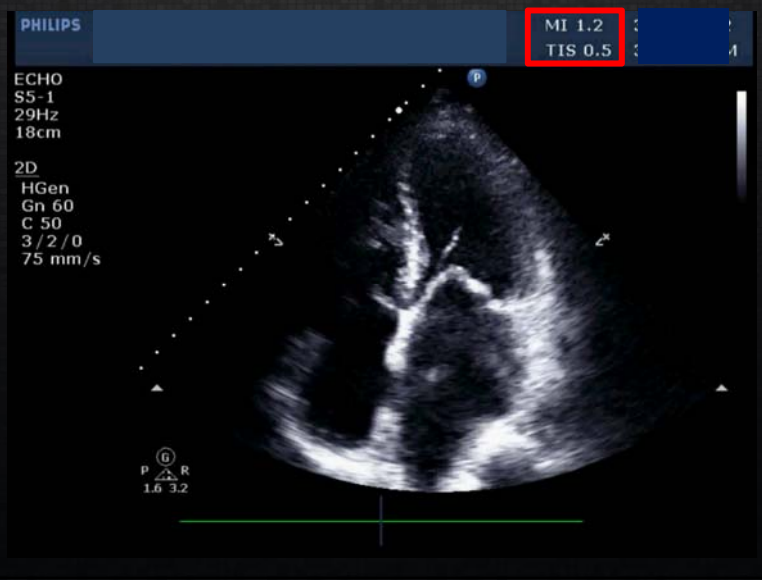


Human Grayscale

- Humans perceive approximately **30 shades** of gray
- Cones are high bandwidth and allow humans to see at least **10 million shades** of color



Echo Screen Anatomy



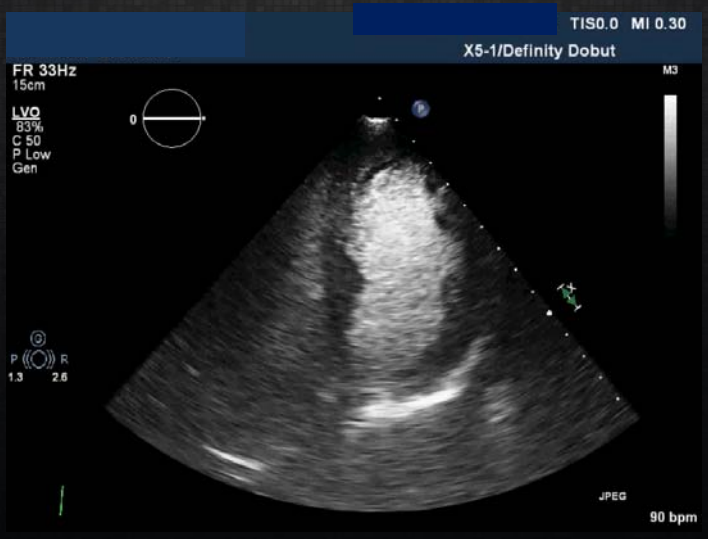
Ultrasound Bioeffects

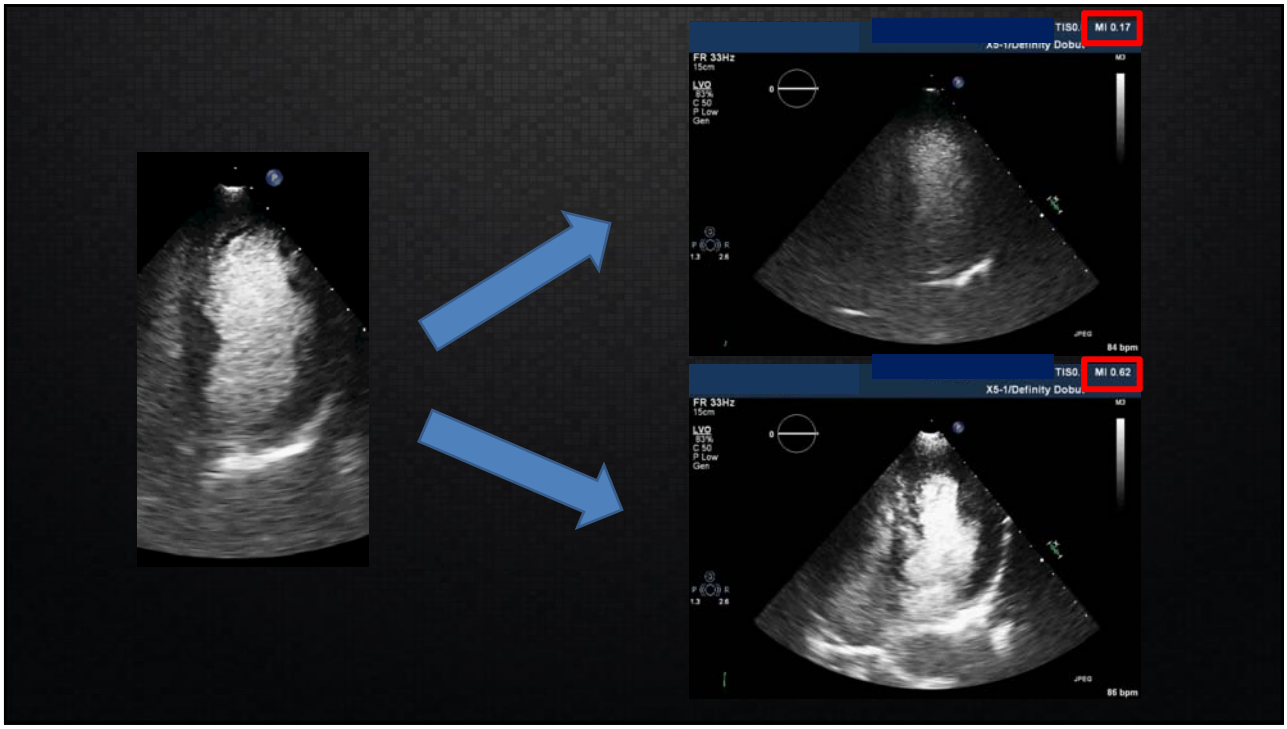
- ✓ Ultrasound is mechanical energy
  - Thermal effects
  - Mechanical effects
- ✓ Background
  - No evidence that diagnostic ultrasound produces harm
  - Subtle or transient effects not well understood
- ✓ ALARA
  - As Low As Reasonably Achievable

Mechanical Index (MI)

- ✓ Quantification of US acoustic intensity
- ✓ MI = P(Pascals)/√Frequency(MHz)
- ✓ Non-thermal (Mechanical) Bioeffects
  - MI expresses the acoustic pressure of US beam on insonated structures
- ✓ Lower MI induces increased bubble resonance and harmonics

Low MI Example





Thermal Index (TI)

- ✓ Quantification of potential for tissue heating
  - As ultrasound travels through tissue energy is absorbed by tissue and converted to heat
  - Frequency and intensity dependent
- ✓ Recommendation is to keep tissue heating < 1.5 °C
  - Caution with the febrile patient
- ✓ Thermal Bioeffects

Doppler Echocardiography

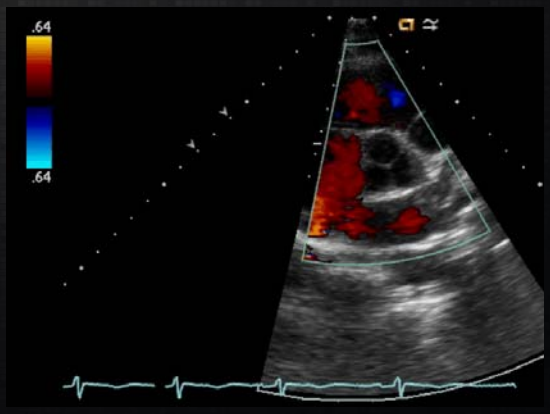
- ✓ Optimal 2D images when ultrasound beam is perpendicular to structures
- ✓ Optimal Doppler imaging when ultrasound beam is parallel to flow
- ✓ Apical views allow alignment with most cardiac flows (i.e. aortic, mitral and tricuspid valves)

Doppler Echocardiography

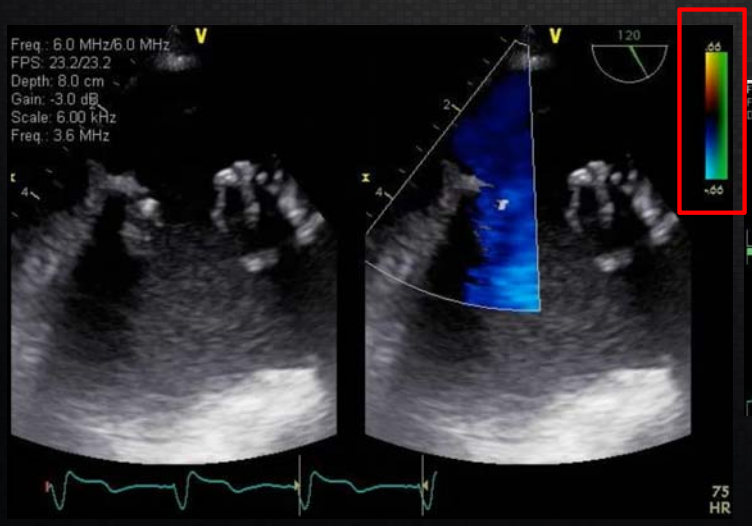
- ✓ Color Flow Doppler
  - Pulse wave modality that cannot resolve high velocities
  - Turbulence/variance maps can help define jet, direction and turbulence
- ✓ Pulse Wave Spectral Doppler
  - Range specific
  - Subject to aliasing at high velocities like CFD
- ✓ Continuous Wave Spectral Doppler
  - Able to resolve high velocities
  - Range ambiguous

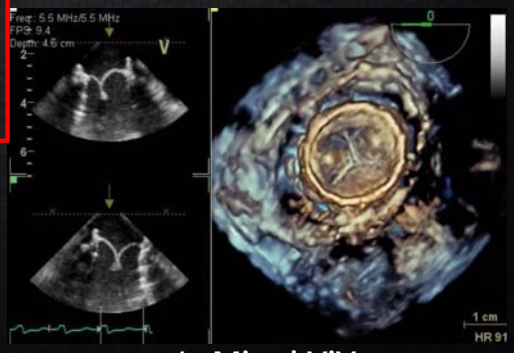
Color Flow Doppler

- Pay attention to the baseline
- Make note of the Nyquist limit
- Color scales vary
- Variance maps (see example)
- Optimize size of box and sector for frame rate



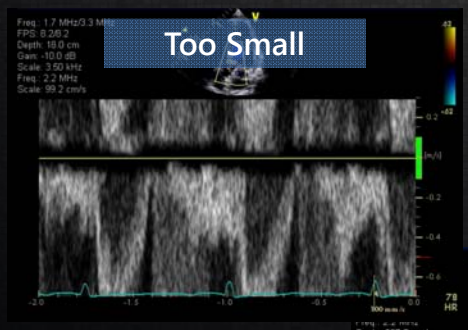
Variance Map

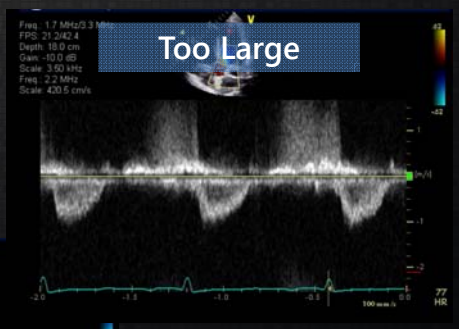


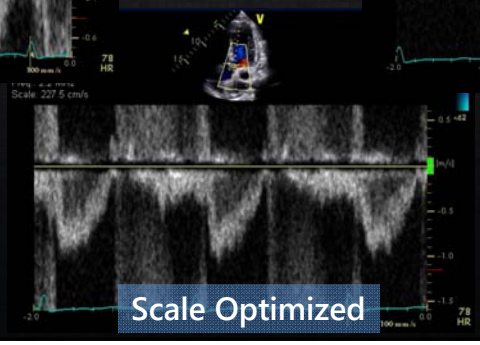


s/p Mitral ViV
S3 26 mm

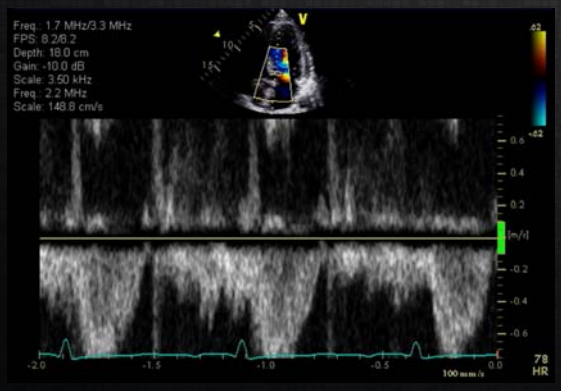
Spectral Doppler Scale

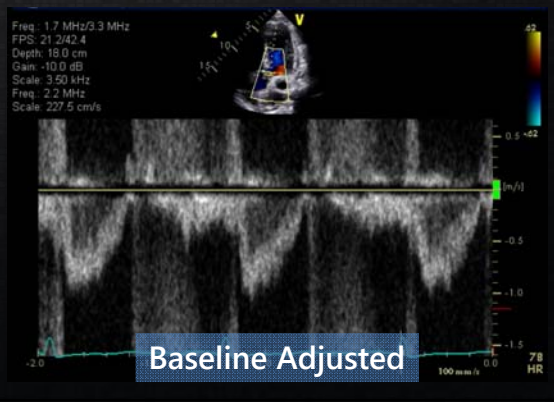




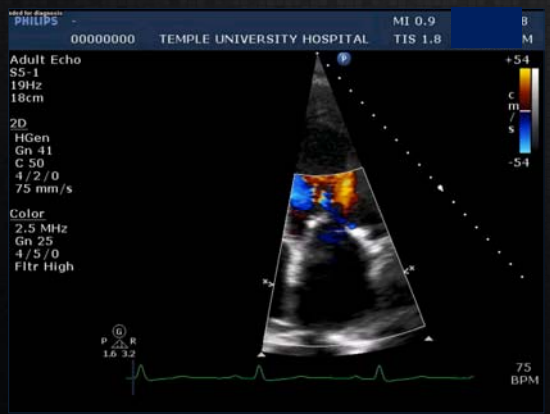


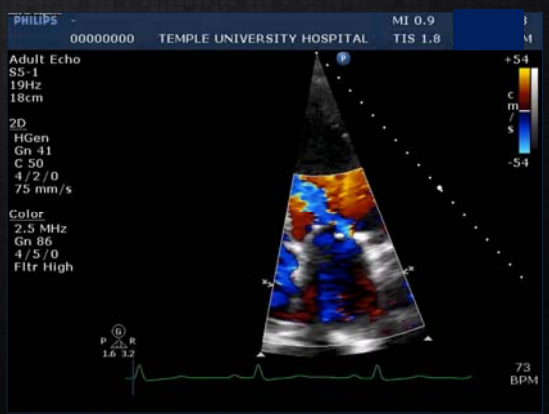
Spectral Doppler Baseline



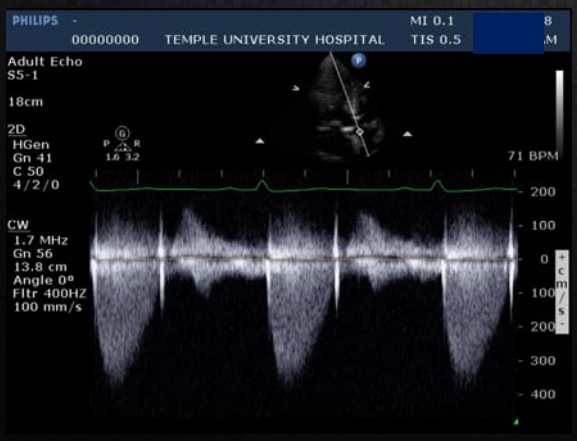


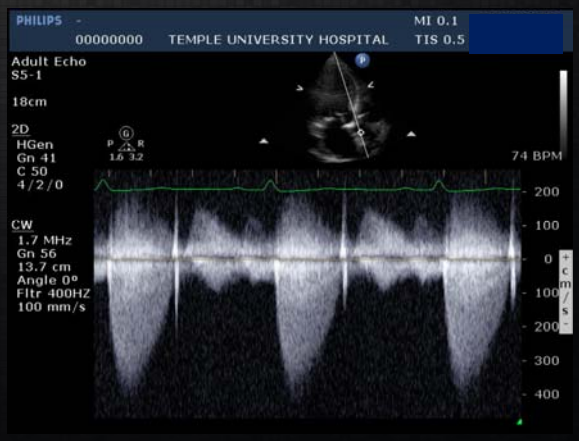
Doppler Gain



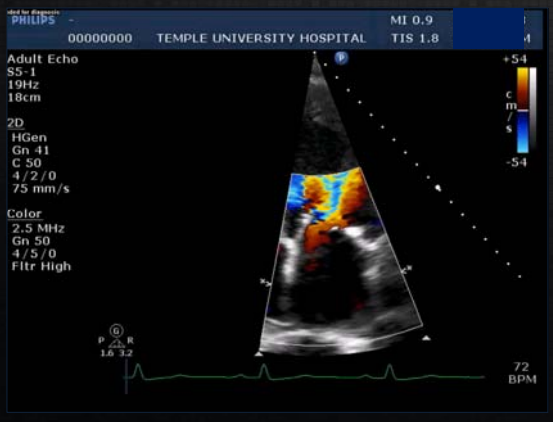


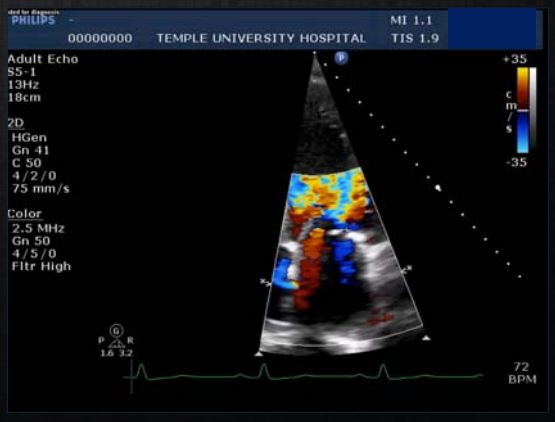
Doppler Gain



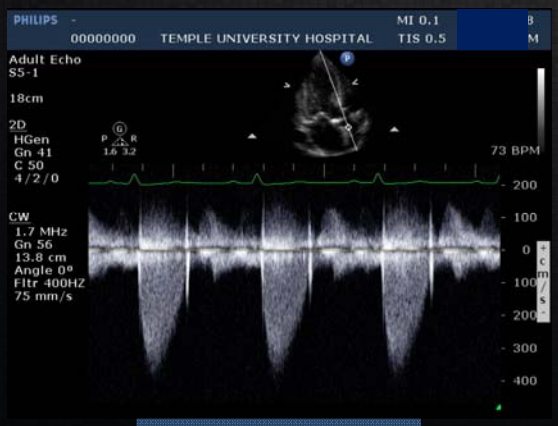


Nyquist Limit

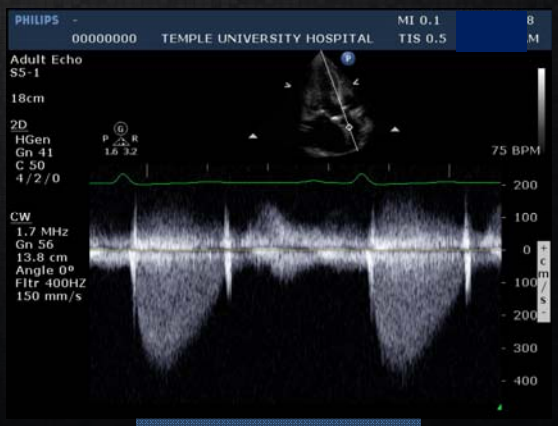




Doppler Sweep



75 mm/s



150 mm/s

ASCeXAM Focus

- ✓ Image optimization "Knobology" is part of achieving competency in echocardiography
- ✓ Key components of image optimization
  - 2D Gain
  - Compression
  - Mechanical index
  - Harmonic Imaging
  - Frame Rate
  - Resolution
  - Depth
  - Doppler Gain
  - Doppler Sweep/Scale


Thank You!